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The first troglobiotic species of the family Pudeoniscidae (Crustacea, Isopoda, Oniscidea), with descriptions of a new genus and two new species

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Abstract

Approximately 170 species of terrestrial isopods are known from Brazil, but only 12 are considered troglobionts. The family Pudeoniscidae comprises four species in two genera, *Brasiloniscus* and *Pudeoniscus*. After the examination of material collected in caves in the state of Bahia, a new genus and two new species have been recognized, *Iansaoniscus iraquara* **gen. et sp. n.** from Buraco do Cão cave, Iraquara, and *Iansaoniscus georginae* **gen. et sp. n.** from Borboletas cave, Paripiranga. The new genus and new species are placed in Pudeoniscidae on the basis of some morphological characteristics, such as antennal flagellum with second and third articles divided by a slender suture, epimera of pereonite 1 with dorsolateral furrow reduced or absent, and shape of uropods. The Brazilian subterranean environments are now under potential threat because of recent legislation for cave exploitation, and the knowledge of the subterranean biodiversity of the country is thus of primary importance for its effective conservation.

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Keywords
New species, terrestrial isopods, Pudeoniscidae, Neotropical, Brazilian Atlantic Forest

Introduction

Terrestrial isopods (Oniscidea) constitute one of the most diverse groups within Isopoda, including more than 3,700 described species (Sfenthourakis and Taiti 2015). Among this diversity, more than 300 species of troglobiotic terrestrial isopods are known in the world (Taiti 2004, 2014, 2016; Taiti and Gruber 2008; Taiti and Xue 2012; Tabacaru and Giurginca 2013; Campos-Filho et al. 2014, 2015a, 2016, in press; Souza et al. 2015; Taiti and Wynne 2015a).

Brazil is considered to be one of the most biodiverse countries in the world due to its great diversity of ecosystems (Mittermeier et al. 2005), with high rates of endemism, and most of them are classified as priorities for conservation (Myers et al. 2000). Brazil has more than 15,000 caves in different lithologies, including limestone, sandstone, magmatic and iron ore, representing 7% of the total estimated number of caves in the country (Auler 2002; Williams 2008; Sallun Filho and Karmann 2012; CECAV 2015).

To date, approximately 170 species of terrestrial isopods are known from Brazil, of which 34 are recorded from caves (Souza-Kury 1993; Souza et al. 2006, 2015; Campos-Filho and Araujo 2011; Campos-Filho et al. 2014, 2015b, 2016, 2017, in press; Souza et al. 2015; Cardoso et al. 2016; Bastos-Pereira et al. 2017). Among these cave dwelling species, only 12 are considered to be troglobionts, i.e. *Cylindroniscus flaviae* Campos-Filho, Araujo & Taiti, in press, *Iuiuniscus iuiuensis* Souza, Ferreira & Senna, 2015, *Spelunconiscus castroi* Campos-Filho, Araujo & Taiti, 2014, *Xangoniscus aganju* Campos-Filho, Araujo & Taiti, 2014, *Xangoniscus itacarambiensis* Bastos-Pereira, Souza & Ferreira, 2017 and *Xangoniscus odara* Campos-Filho, Bichuette & Taiti, 2016 (Styloniscidae), *Leonardoscia hassalli* Campos-Filho, Araujo & Taiti, 2014 (Philosciidae), *Amazoniscus eleonorae* Souza, Bezerra & Araújo, 2006, *Amazoniscus leistikowi* Campos-Filho, Araujo & Taiti, 2014, *Circoniscus buckupi* Campos-Filho & Araujo, 2011, *Circoniscus carajasensis* Campos-Filho & Araujo, 2011 (Scleropactidae), and *Trichorhina guanophila* Souza-Kury, 1993 (Platyarthridae).

The family Pudeoniscidae Lemos de Castro, 1973 comprises four species in two genera, *Brasiloniscus* Lemos de Castro, 1973, and *Pudeoniscus* Vandel, 1963 (Lemos de Castro 1973). The family has a restricted distribution in the Atlantic Forest of Brazil.

In the present work, a new genus and two new species of Pudeoniscidae from limestone caves in the state of Bahia are described, representing the first troglobiotic taxa within the family. Moreover, additional characters are proposed as diagnostic to the family, in order to accommodate the new taxa described here.

Material and methods

The material was stored in 75% ethanol and identifications were based on morphological characters. The species were illustrated with the aid of a camera lucida mounted on Wild M5 and M20 microscopes. The final illustrations were prepared using the software GIMP with the method proposed by Montesanto (2015, 2016). The material used in this study is deposited in the Museu de Zoologia, Universidade de São Paulo, São Paulo, Brazil (MZUSP) and Laboratório de Estudos Subterrâneos, Universidade Federal de São Carlos (LES/UFSCar).

Study area

Espinhaço Supergroup, Una Group, Irecê metasedimentary Basin, Salitre Formation: Iraquara, Buraco do Cão cave

Buraco do Cão cave is located in an area geographically known as Chapada Diamantina, in the central portion of the state of Bahia, northeastern Brazil (Fig. 1). The Chapada

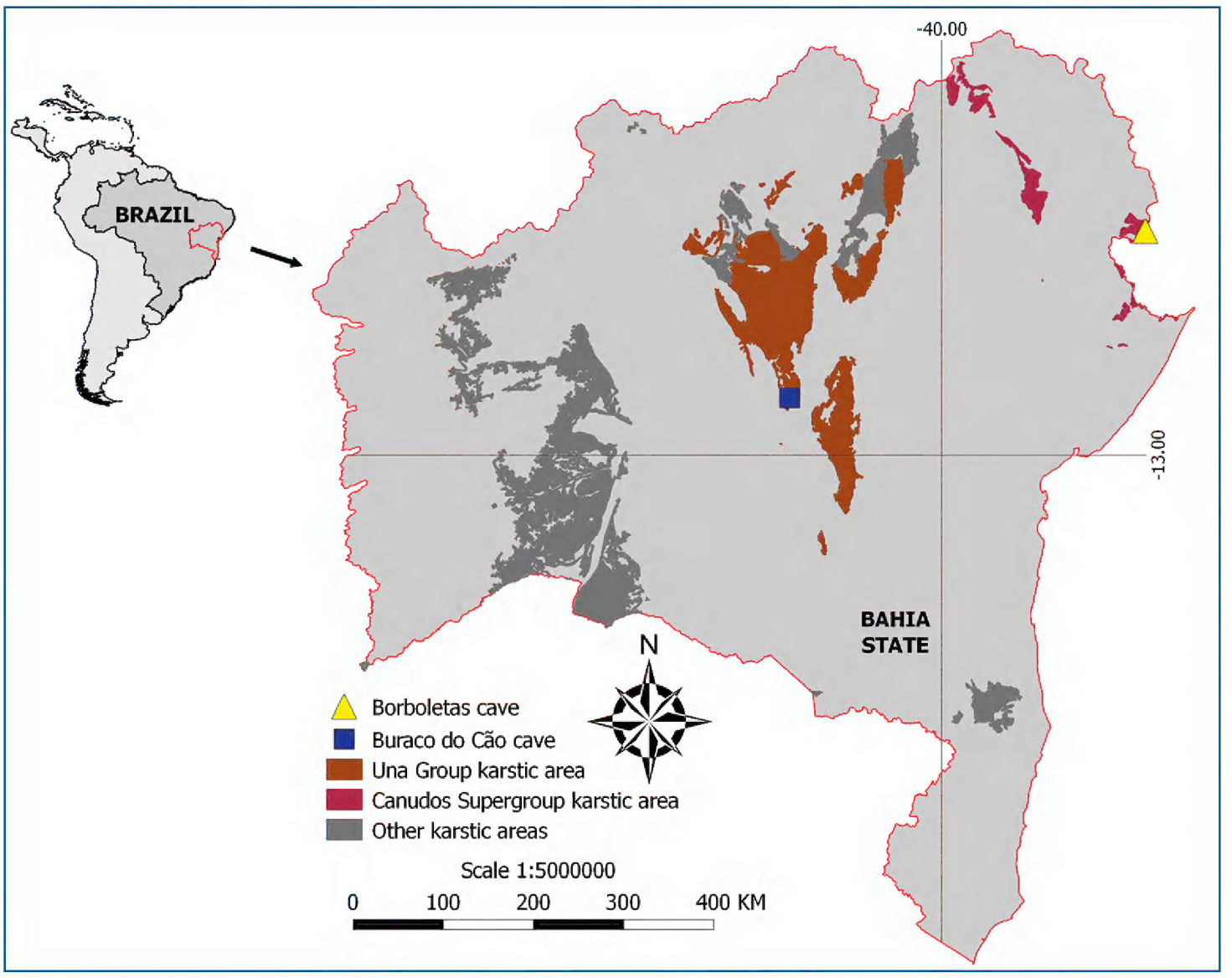

Figure 1. Locality map of Buraco do Cão and Borboletas caves.

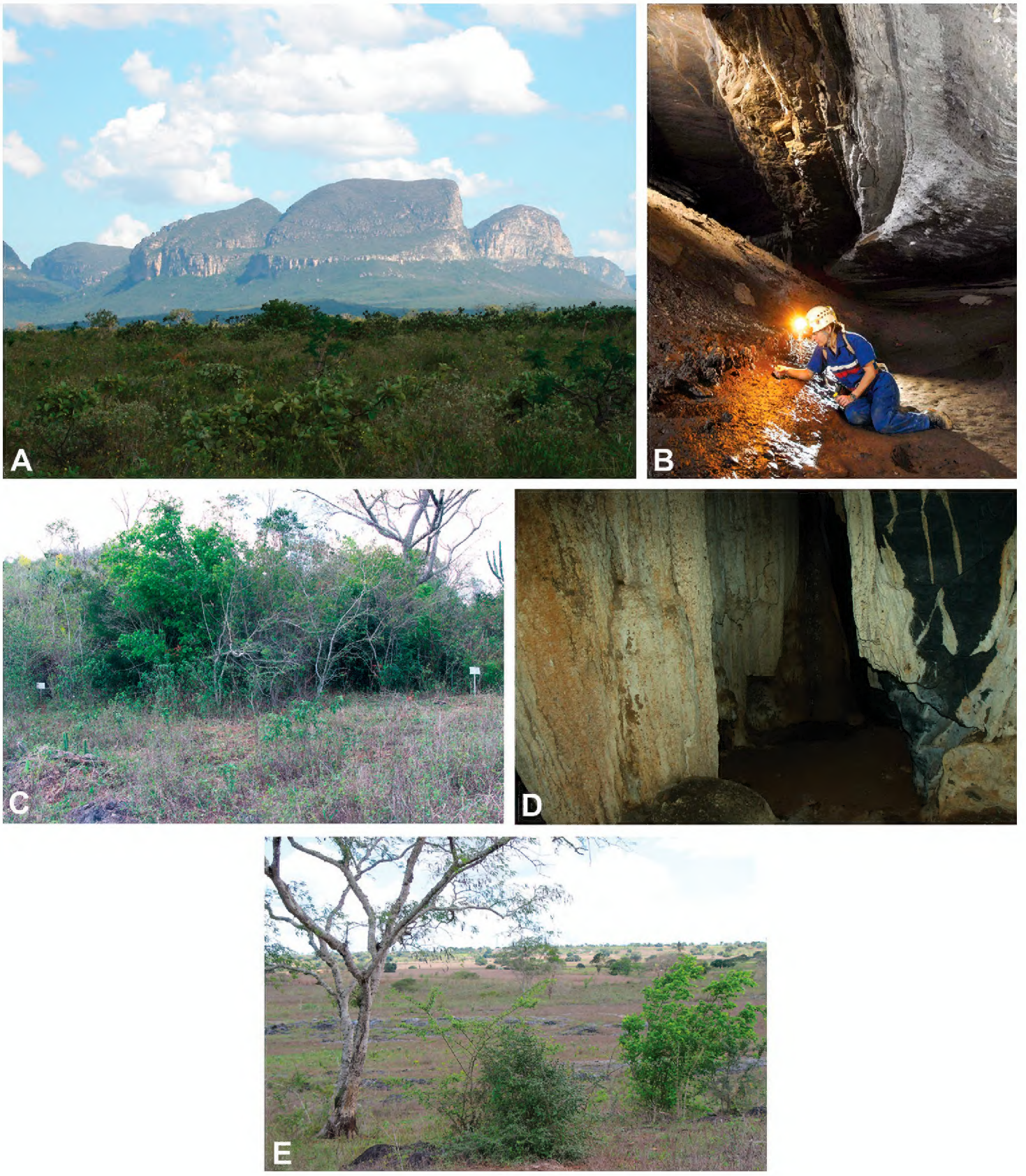

Figure 2. A Landscape of Chapada Diamantina, central portion of the state of Bahia, Caatinga vegetation in the foreground **B** Buraco do Cão cave, type locality of *Iansaoniscus iraquara* sp. n., silt and rocky substrates, humid environment **C** Caatinga vegetation close to Borboletas cave, Paripiranga, Bahia **D** Borboletas cave, type locality of *Iansaoniscus georginae* sp. n., silt and rocky substrates, humid environment **E** Deforested landscape from Paripiranga region.

Diamantina landscape is dominated by karst landforms formed by the dissolution of carbonatic and, to a lesser extent, siliciclastic rocks. The carbonatic rocks (limestones) date from Neoproterozoic age (1,000 to 541 million years ago). The climate domain is Aw, Tropical Savanna climate (Köppen and Geiger classification), with average temperature of 22.1 °C and annual rainfall of 761 mm concentrated between November

and April (Kottek et al. 2006). The cave is inserted in the Caatinga domain (Ab'Saber 1977), with typical dry vegetation interspersed by Atlantic Forest remnants (Fig. 2A).

Buraco do Cão is part the Talhão-Buraco do Cão-Gruta da Santa system with ca. 6.5 km of mapped passageways (Grupo Bambuí de Pesquisa Espelológicas, ME Bichuette, pers. comm.), and shows a high diversity of substrates that can be exploited by fauna – silt, guano piles, parietal substrate, etc. (Fig. 2B). To date, at least two exclusively troglobiotic species have been recorded in this cave, a pseudoscorpion (DM von Schimonsky and ME Bichuette, in prep.), and the terrestrial isopod in the family Pudeoniscidae described herein.

Buraco do Cão cave is located outside the Chapada Diamantina National Park (CDNP) and part of the cave galleries are visited by tourists since the '90s. The cave has no management plan and is subject to local environmental impacts related to poorly regulated speleotourism (Trajano et al. 2016). However, the main threats in Iraquara region are the drastic and uncontrolled exploration of the subterranean waters and the pollution of the aquifers by pesticides. The level of subterranean waters is decreasing drastically in the last two years (ME Bichuette, pers. obs.), something that could alter not only the aquatic ecosystem functions but also the habitats related to the system, including terrestrial ones.

Canudos Supergroup, Vaza Barris Group, Olhos D'agua Formation: Paripiranga, Borboletas cave

The region of Paripiranga is located in the state of Bahia, northeastern Brazil (Fig. 1). The region consists of carbonated phyllite intensely sheared hills with a maximum elevation of 430 m. In this area one may also find meta-calcareous rocks, which are in tectonic contact with the carbonated phyllite. The limestone dates from the Neoproterozoic (1,000 to 541 million years ago) (Pereira et al. 2017). The climate domain is Aw, Tropical savanna climate (Köppen and Geiger classification), with average temperature of 22.6 °C and annual rainfall of 897 mm concentrated between March and September (Kottek et al. 2006). The cave is inserted in the Caatinga domain (Ab'Saber 1977), with typical dry heterogeneous vegetation in the surroundings, named "Campo Rupestre", and with Atlantic Rainforest present in the highlands (Fig. 2C). To date, 82 caves are recorded in the region (CECAV 2015), including Borboletas cave with an extension of about 100 m (Fig. 2D). The region has not legal protection, suffers impact by agriculture and pastures (Fig. 2E) and, more recently, by extraction of limestone for cement production.

Results

Pudeoniscidae Lemos de Castro, 1973

***Iansaoniscus* Campos-Filho, Araujo & Taiti, gen. n.**
http://zoobank.org/59969B35-C6D0-4E10-94AC-C2150E02DDE8

Type species. *Iansaoniscus iraquara* Campos-Filho, Araujo & Taiti, sp. n. by present designation.

Diagnosis. Body convex. Animals unable to roll up into a ball. Cephalon with well-developed antennary lobes, slightly developed triangular frontal shield, laterally interrupted by antennal grooves, frontal line delimiting frontal shield on upper portion, suprantennal line absent. Pereonite 1 epimeron with dorsolateral furrow reduced or absent. Pleon outline continuous with that of pereon. Telson triangular, surpassing uropod endopods. Antenna with flagellum of three articles, second and third articles divided by thin suture. Mandible with molar penicil dichotomized. Maxillula outer branch with some cleft teeth. Uropod protopod sub-quadrangular. Pleopod exopods with no respiratory structures.

Etymology. The new genus is named after Iansã Orisha, the Afro-Brazilian divinity of the winds and thunderbolts, known as the divinity who commands the storms and the spirit of the dead.

Remarks. *Iansaoniscus* gen. n. is included in the family Pudeoniscidae by having the cephalon with a triangular frontal shield, pereonites 1 and 2 with small ventral lobes, telson with distal portion surpassing the uropod endopods, antennal flagellum with second and third articles divided by a slender suture, and the characteristic Pudeoniscidae-type shape of uropods (see Schmidt 2003).

Iansaoniscus gen. n. differs from the other genera of the family in lacking or having a reduced dorsolateral furrow on the epimeron of the pereonite 1 and in pleopod exopods without respiratory structures.

The dorsolateral furrow on the epimeron of the pereonite 1 and pleopodal exopods with uncovered lungs were considered to be diagnostic characters for the family Pudeoniscidae (Vandel 1963; Lemos de Castro 1973). Thus, regarding these two characters, the diagnosis of the family must be emended as follows: epimera of pereonite 1 with dorsolateral furrows to fit antennae during conglobation, sometimes reduced or absent; pleopodal exopods with respiratory structures, absent in troglobiotic taxa.

The absence of respiratory structures in the pleopodal exopods of the species of *Iansaoniscus* gen. n. may be due to secondary reduction due to the humid environment in the caves. Other families of Oniscidea are known to have genera with and genera without respiratory structures, e.g. Scyphacidae, Philosciidae, Scleropactidae, and Armadillidae (Ferrara et al. 1994; Taiti et al. 1998; Schmidt 2002, 2007).

Iansaoniscus iraquara Campos-Filho, Araujo & Taiti, sp. n.

http://zoobank.org/1F152A88-CE7A-4698-9570-47636CD3835A

Figs 3–5

Type locality. Bahia, Iraquara, Buraco do Cão cave (12°23'37.32"S, 41°36'8.28"W).

Type material. *Holotype* male (MZUSP 27533), Bahia, Iraquara, Buraco do Cão cave, 20 July 2009, leg. ME Bichuette.

Description. Body length: 6.5 mm. Body pigmentless, eyes absent. Body outline in lateral view as in Fig. 3A. Pereonite 1 epimeron without dorsolateral furrow; pere-

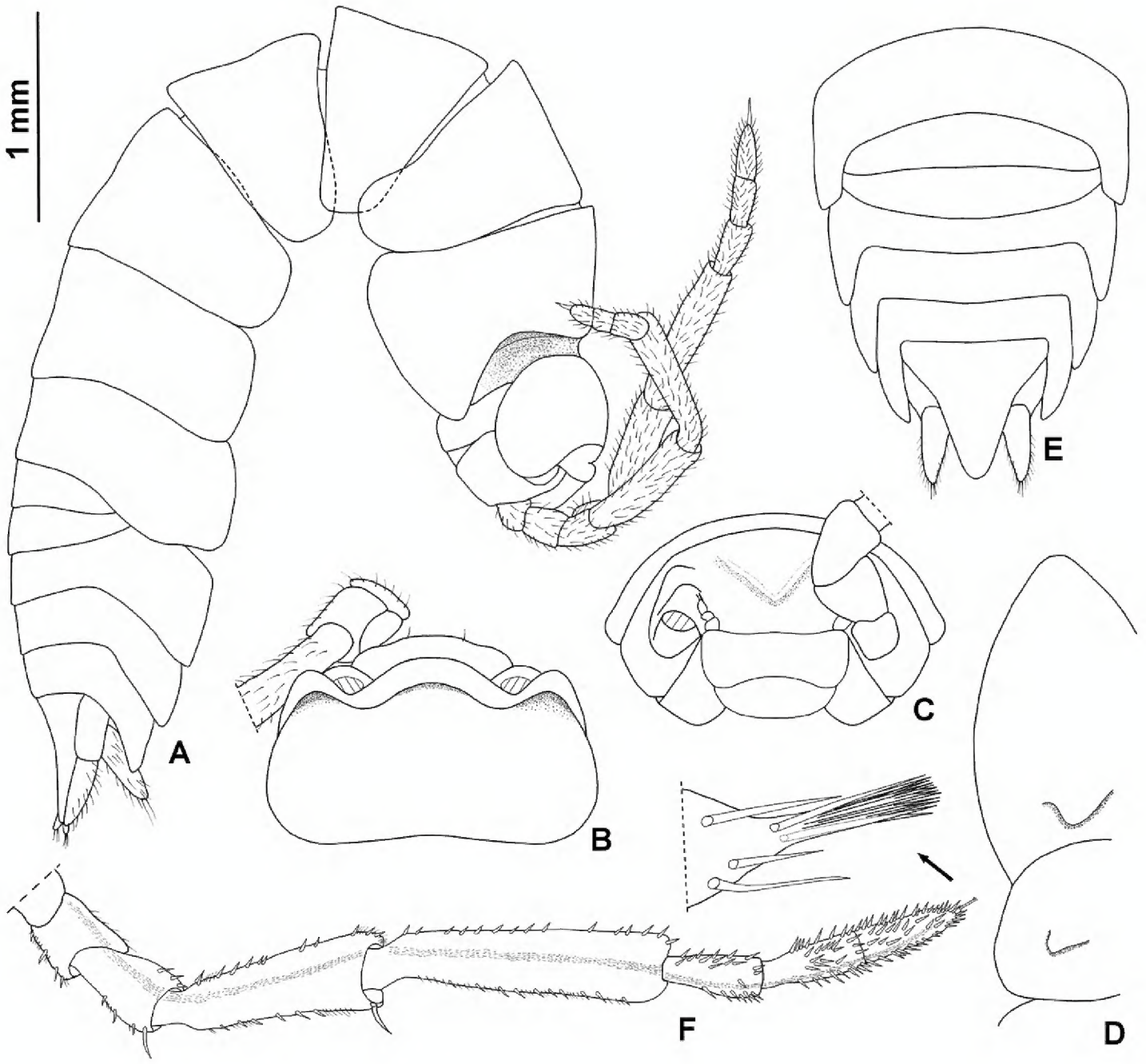

Figure 3. *Iansaoniscus iraquara* sp. n., ♂ holotype, MZUSP 27533. **A** Habitus in lateral view **B** Cephalon, dorsal view **C** Cephalon, frontal view **D** Pereonites 1 and 2, ventral view **E** Pereonite 7, pleon, telson and uropods, dorsal view **F** Antenna.

onite 1 and 2 with ventral triangular lobes (Fig. 3D); pereonite 3–7 with subquadrangular epimera. Cephalon as in Fig. 3B, C. Pleonites 3–5 with epimera subquadrangular and directed backwards (Fig. 3A, E). Telson (Fig. 3E) slightly wider than long with slightly concave sides, narrowly rounded apex. Antennula missing. Antenna (Fig. 3F) with flagellum as long as fifth article of peduncle. Mandibles (Fig. 4A, B) with molar penicil with 5–7 branches, left mandible with 2+1 penicils, right with 1+1 penicils. Maxillula (Fig. 4C) inner endite with distal margin rounded bearing two long penicils; outer endite of 4+5 teeth (two apically cleft). Maxilla (Fig. 4D) outer lobe twice as wide as inner lobe, rounded and covered with thin setae; inner lobe bearing thick setae. Maxilliped (Fig. 4E) basis rectangular; basal article of palp with two setae distinct in length; endite subrectangular, medial seta surpassing distal margin. Uropod (Fig. 5A) protopod with glandular pores on outer groove, exopod as long as endopod. Pereopod 1–7 (Fig. 5B, C) merus and carpus with slightly

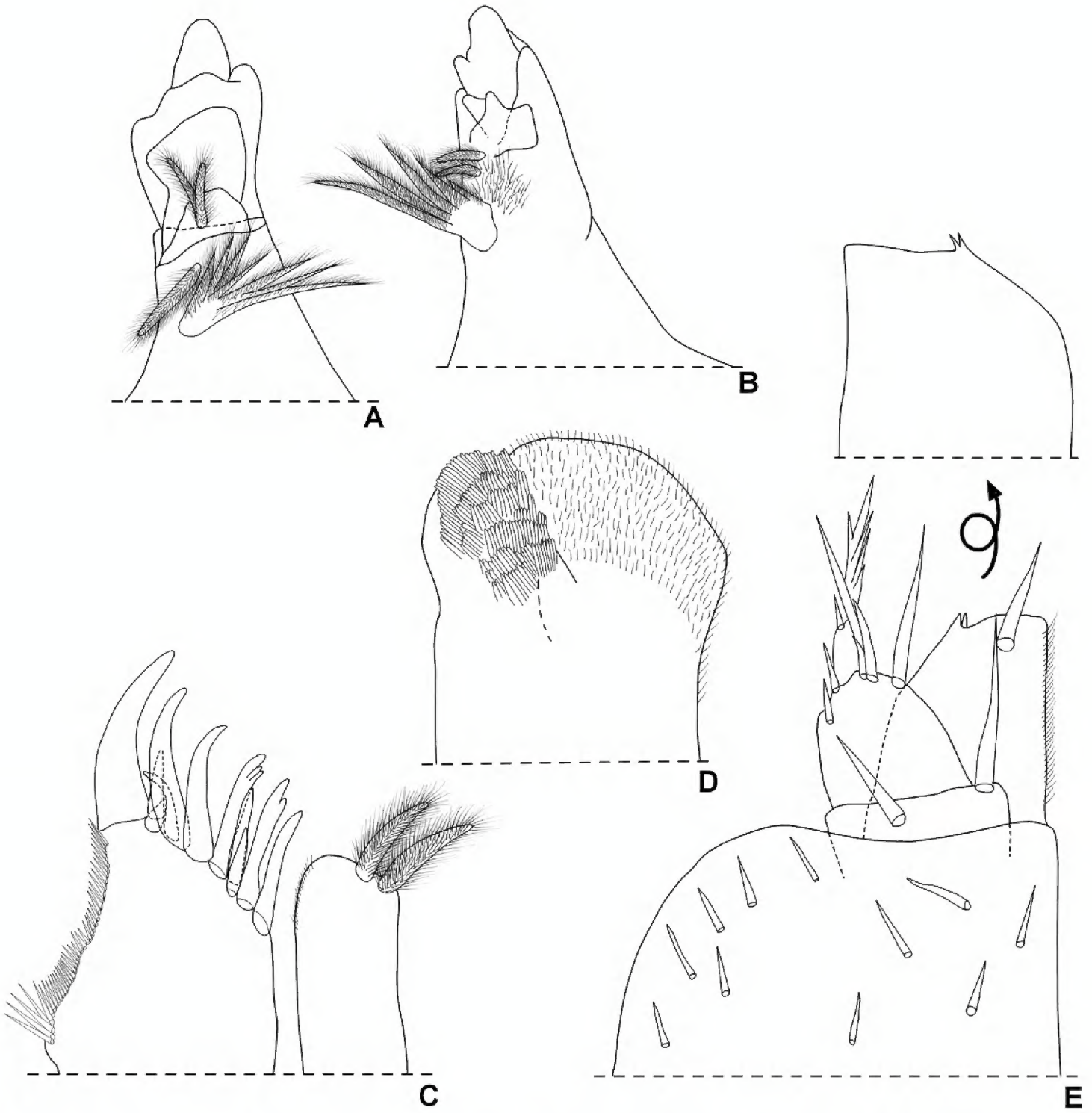

Figure 4. *Iansaoniscus iraquara* sp. n., ♂ holotype, MZUSP 27533. **A** Left mandible **B** Right mandible **C** Maxillula **D** Maxilla **E** Maxilliped.

sparse setae on sternal margin; carpus 1 with antennal grooming brush transverse, distal seta apically with four points; dactylus with dactylar seta and ungual seta simple not surpassing outer claw. Genital papilla missing. Pleopod 1 (Fig. 5D) exopod ovoid, twice as wide as long; endopod almost three times as long as exopod, distal portion slightly bent outwards, inner margin bearing small setae. Pleopod 2 exopod (Fig. 5E) triangular bearing three setae on outer margin. Pleopod 3–5 exopods as in Fig. 5F–H.

Etymology. The new species is named after the Tupi language, spoken by the Brazilian native people, that inhabited the littoral zone. In Tupi, Iraquara means Honey Cave ("*Ira*" = honey + "*quara*" = cave). Actually, the city of Iraquara is also known as the "City of the Caves".

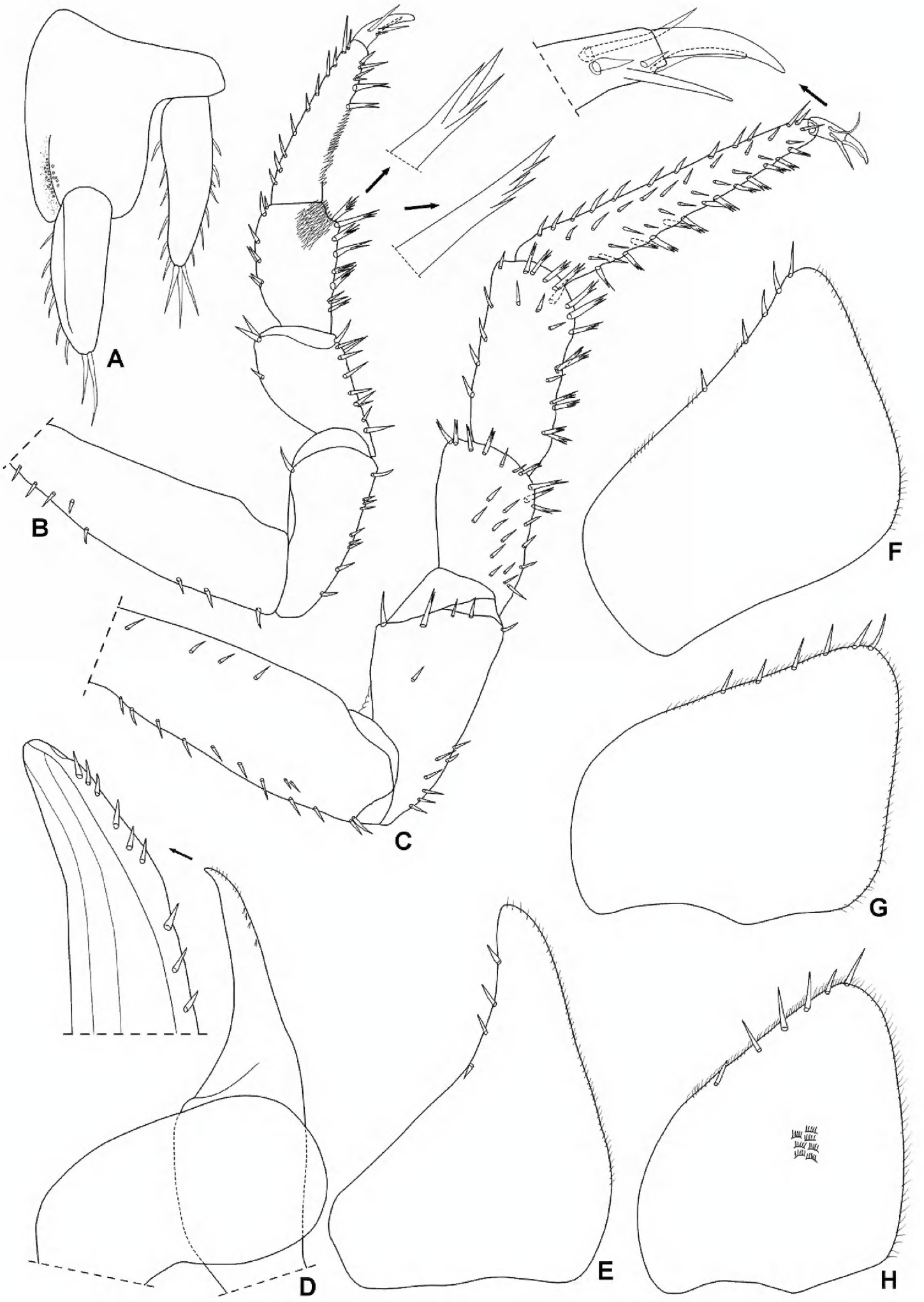

Figure 5. *Iansaoniscus iraquara* sp. n., ♂ holotype, MZUSP 27533. **A** Uropod **B** Pereopod 1 **C** Pereopod 7 **D** Pleopod 1 **E** Pleopod 2 exopod **F** Pleopod 3 exopod **G** Pleopod 4 exopod **H** Pleopod 5 exopod.

***Iansaoniscus georginae* Campos-Filho, Araujo & Taiti, sp. n.**
http://zoobank.org/85D9F0DD-2B40-45C0-A650-C2F98F809813
Figs 6–8

Type locality. Bahia, Paripiranga, Caverna das Borboletas cave (10°38'12.75"S, 43°51'43.68"W).

Type material. *Holotype* male (part in micropreparations) (MZUSP 35114), Bahia, Paripiranga, Borboletas cave, leg. JE Gallão, MP Bolfarini, MJ Rosendo, R Moreira.

Description. Body length: 5 mm. Body pigmentless, eyes absent. Body outline in lateral view as in Fig. 6A. Dorsum covered with triangular, elongated scale-setae (Fig. 6B). Pereonite 1 epimeron with dorsolateral furrow weakly developed, anterior and posterior corners triangular; pereonite 1 and 2 ventrally with weakly developed lobes (Fig. 6A, E); pereonite 2–7 with subquadrangular epimera. Cephalon as in Fig. 6C, D. Pleonites 3–5 (Fig. 6A, F) with subrectangular epimera directed backwards. Telson (Fig. 6F) almost as wide as long, not surpassing uropod exopods. Antennula (Fig. 6G) with second article bearing thick lateral setae, distal article with 4 lateral aesthetascs plus apical pair. Antenna missing. Mandibles (Fig. 7A, B) with molar penicil with 6–7 branches, left mandible with 2+1 penicils, right with 1+1 penicils. Maxillula (Fig. 7C) inner endite with two penicils, distal margin rounded; outer endite of 4+6 teeth (two apically cleft). Maxilla (Fig. 7D) outer lobe twice as wide as inner lobe, rounded and covered with thin setae; inner lobe bearing thick setae. Maxilliped (Fig. 7E) with basal article of palp bearing two setae distinct in length; endite subrectangular, medial seta surpassing distal margin. Uropod (Fig. 8A) protopod with glandular pores on outer groove, exopod slightly longer than endopod. Pereopod 1–7 (Fig. 8B, C) merus and carpus with slightly sparse setae on sternal margin; carpus 1 with antennal grooming brush transverse, distal seta apically with five points; dactylus with dactylar seta and ungual seta simple not surpassing outer claw. Genital papilla (Fig. 8D) with triangular ventral shield and subapical orifices. Pleopod 1 (Fig. 8E) exopod subquarangular, twice as wide as long; endopod almost three times as long as exopod, inner margin bearing small setae. Pleopod 2 (Fig. 8F) exopod triangular bearing one seta on outer margin; endopod very long, more than three times as long as exopod. Pleopod 3–5 exopods as in Fig. 8G–I.

Etymology. The new species is named after Dr. Georgina Bond-Buckup for all her contributions to the knowledge of crustaceans, including Oniscidea.

Remarks. *Iansaoniscus georginae* sp. n. is readily distinguishable from *I. iraquara* sp. n. in the shape of the cephalon, epimeron of pereonite 1 with reduced dorsolateral furrow, shape of ventral lobes on pereonites 1 and 2, and shape of the male pleopods 1 and 2.

Considerations about conservation

Iraquara and Paripiranga show different historical sampling efforts: Iraquara has been sampled since 1990, and Paripiranga after 2014 (M.E. Bichuette, pers. obs.). The two species are extremely rare and represent the first records of troglobiotic species in the family Pudeoniscidae. These records increase the taxonomic distinctness of these two

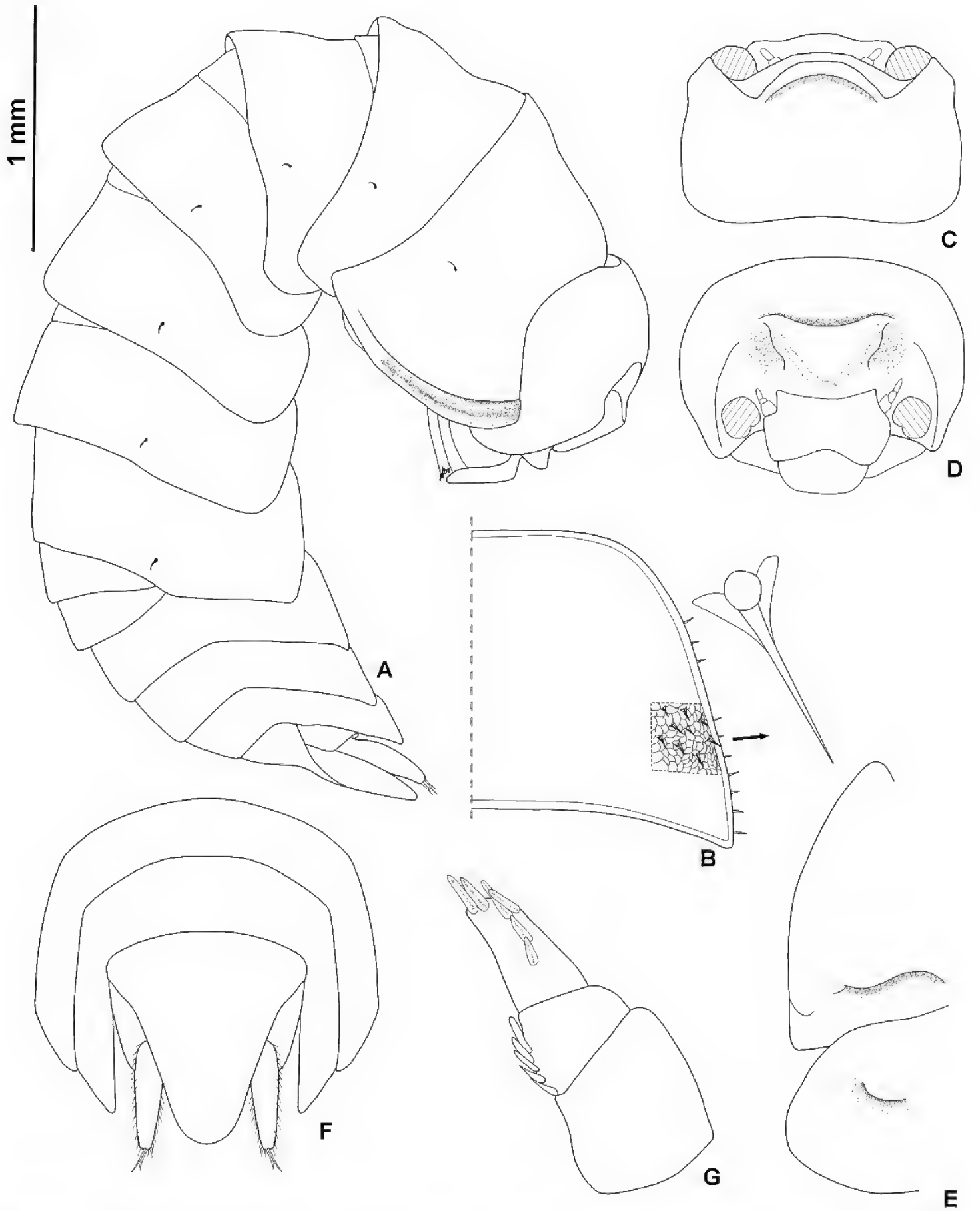

Figure 6. *Iansaoniscus georginae* sp. n., ♂ holotype, MZUSP 35114. **A** Habitus in lateral view **B** Pereonite 1 and scale-seta, dorsal view **C** Cephalon, dorsal view **D** Cephalon, frontal view **E** Pereonite 1 and 2, ventral view **F** Pleonites 4 and 5, telson, and uropods, dorsal view **G** antennula.

regions and, consequently, their importance for conservation (BRASIL 1990, 2008). Both regions have no legal protection acts and have been suffering with serious impacts. The Iraquara region is affected by touristic activities, lowering and pollution of the phreatic water due to agriculture activities. The Paripiranga region suffers deforestation due to agriculture and pastures (Fig. 2E), but the main threat is the use of the limestone

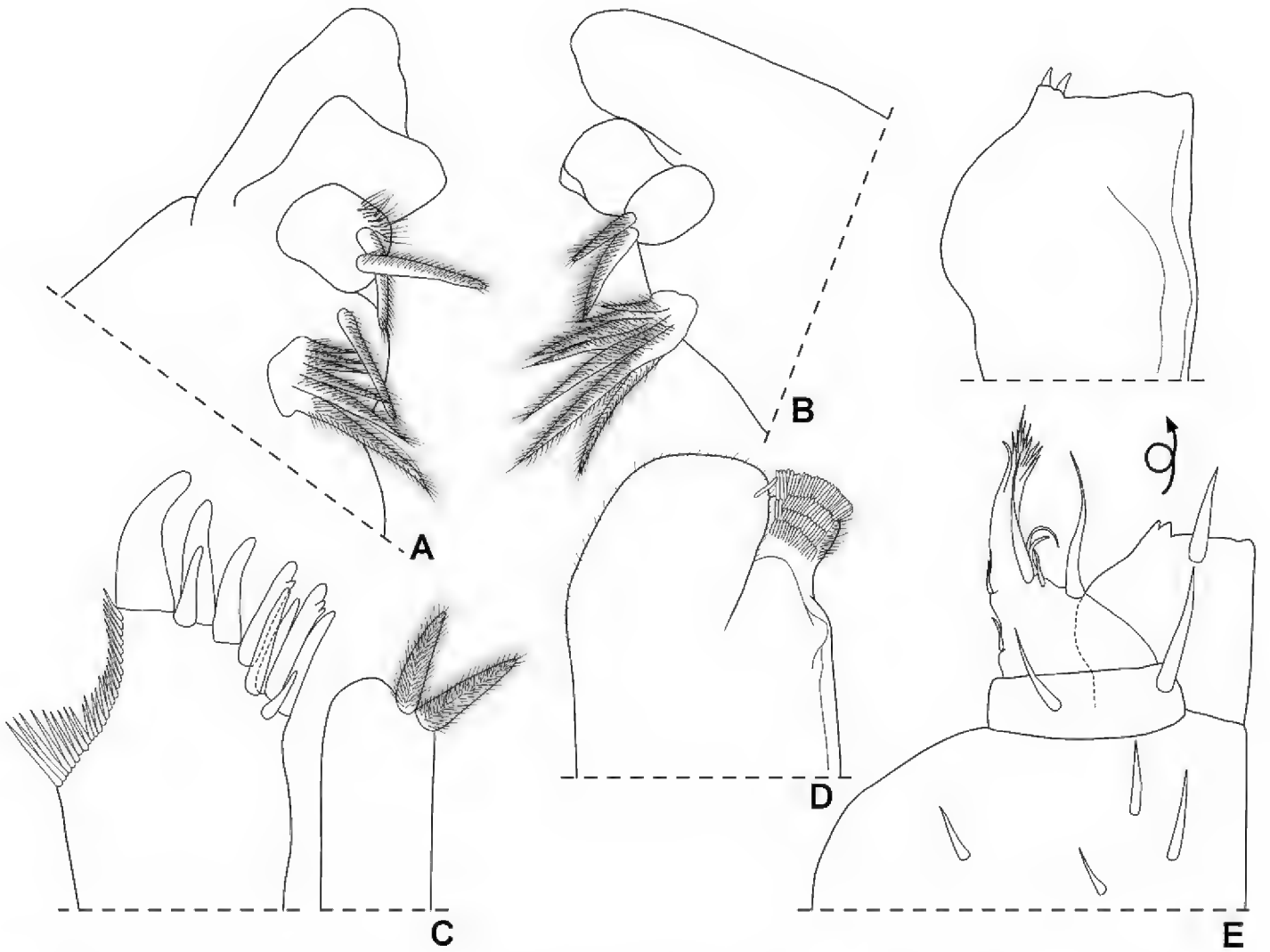

Figure 7. *Iansaoniscus georginae* sp. n., ♂ holotype, MZUSP 35114. **A** Left mandible **B** Right mandible **C** Maxillula **D** Maxilla **E** Maxilliped.

rocks for cement production. In conclusion, considering the rarity and a possibly relictual distribution of both species, *Iansaoniscus iraquara* sp. n. and *I. georginae* sp. n. can be considered as highly threatened and conservations actions studies about their distribution and ecology are urgently needed in order to effectively preserve these fragile species.

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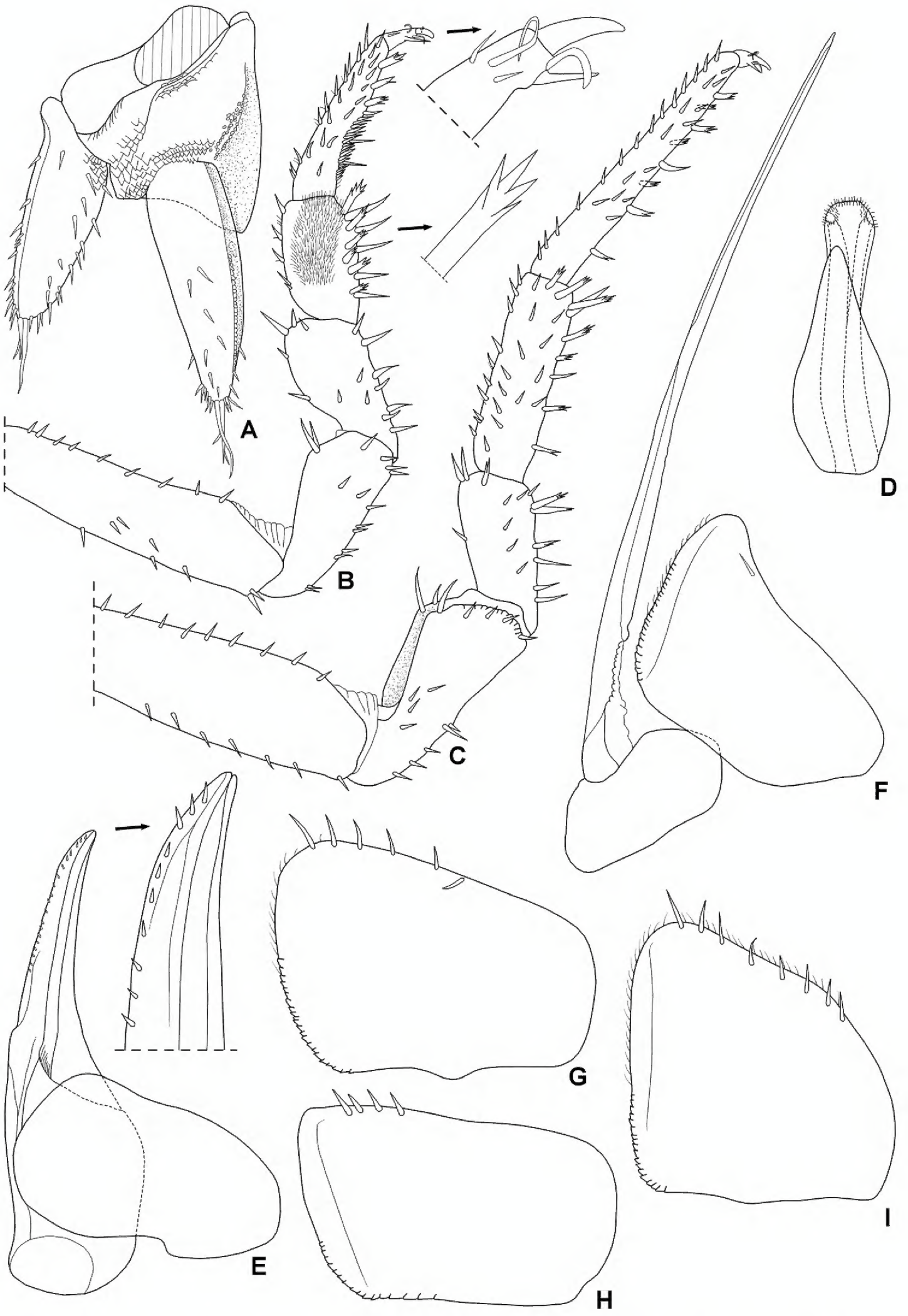

Figure 8. *Iansaoniscus georginae* sp. n., ♂ holotype, MZUSP 35114. **A** Uropod **B** Pereopod 1 **C** Pereopod 7 **D** Genital papilla **E** Pleopod 1 **F** Pleopod 2 **G** Pleopod 3 exopod **H** Pleopod 4 exopod **I** Pleopod 5 exopod.

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